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Construction, delivery, and testing of a flow-cell to measure adhesion strengths of hard-fouling organisms on foul-release coatings in Hawaii.

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**13. ABSTRACT (Maximum 200 words)**

A precision flow cell for measuring shear stresses exerted on hard fouling organisms attached to experimental coatings was constructed at Harbor Branch Oceanographic Institution, delivered to the Kewalo Marine Laboratory (KML) of the University of Hawaii, assembled, and calibrated. The flow cell was equipped at the KML with a binocular microscope to which a video camera is attached, allowing simultaneous viewing and videotaping of attached hard-fouling organisms (principally the polychaete tube worm *Hydroides elegans* and the barnacle *Balanus amphitrite*) as they are subjected to increasing flow velocities, and thus shear stresses, in natural seawater. Tests of glass surfaces demonstrated that the hard foulers could not be removed by shear forces comparable to those on the hull of a large naval ship under near maximal speed. Small hard-fouling invertebrates were similarly not removed from a series of silicone-based experimental coatings provided by General Electric's paints dept. We await delivery of other coatings by ONR, DARPA or private developers to further exploit this excellent, precision instrument. Because of the lack of materials for testing, no presentations (other than to ONR) or publications have resulted from this instrument yet.

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# FINAL REPORT

GRANT NO.: N00014-00-1-0755, Mod No. A00001

PRINCIPAL INVESTIGATOR: Dr. Michael G. Hadfield

CO-PRINCIPAL INVESTIGATOR: Dr. Celia M. Smith

GRANT TITLE: Construction, delivery and testing of a flow cell to measure adhesion strengths of hard-fouling organisms on foul-release coatings in Hawaii.

AWARD PERIOD: 1 June 2000 – 30 June 2001

OBJECTIVE: To support construction of a precision flow cell, designed by Dr. Michael Schultz (U.S. Naval Academy), in the Engineering Department at Harbor Branch Oceanographic Institution, delivery and assembly of the flow cell at the Kewalo Marine Laboratory of the University of Hawaii, calibration of the flow cell, and initial testing of its capabilities.

APPROACH: Dr. Schultz provided detailed plans for the construction of the flow cell. When the grant was awarded, the University of Hawaii contracted for its construction at the Harbor Branch Oceanographic Institution (HOBI). This flow cell is the "second generation;" an earlier design (installed at the University of Birmingham, UK) was improved upon by M. Schultz, with suggestions from Hadfield. The cell was completed in October 2000 and then shipped to Hawaii. Lawrence Borne, the principal engineer at HBOI, came the Kewalo Marine Laboratory to unpack and assemble the cell. In Nov., Dr. Schultz came to Hawaii to train the PIs and their staff in the operation of the cell and methods for calculating shear forces generated on test surfaces.

ACCOMPLISHMENTS: Subsequent to its installation, Dr. Hadfield's group has added very useful modifications to the flow cell to make it more quickly useful. They have installated a microscope above a clear plexiglass window to view the test surfaces. The microscope is equipped for precision X, Y and Z movement for easy scanning and focussing upon the test surfaces. Providing magnifications from 5X to 50X, the microscope allows the operator to immediately determine when invertebrate hard foulers have been removed from test surfaces in high-velocity flow. In addition, a video camera has been fitted onto the microscope to allow recording of the removal of fouling organisms as flow rate (and thus sheer forces) is increased. Audio recording on the video tape allows the user to include all information on flow rate on the tape during recording.

The flow cell and video recording has now been utilized to examine removal of a hard-fouling species from clean glass surfaces and a set of coupons bearing experimental silicone-based coatings developed by GE's paints division. The species tested was the tube worm *Hydroides elegans*. Newly settled tubes of *H. elegans* remained on all of these surfaces throughout the tests, even at the maximal flow velocities. If the tubes of *H.*

*elegans* were oriented parallel with the direction of flow, the small worms were blown from the tubes; however, the tubes remained attached to the surfaces.

Tests have also been run to determine the shear forces necessary to remove newly attached spores of the marine alga *Ulva lactuca*. At relatively high values, some of these spores were removed from the GE paints referred to above. However, results were not consistent, and removal of the very small spores could not be evaluated visually, even with the microscope attached to the flow cell. Thus, coated coupons had to be put in the cell, subjected to a set flow speed, and then removed for analysis under a compound microscope.

We have also done preliminary determinations of the shear forces required to remove settled larvae and newly metamorphosed individuals of the coral-eating sea slug *Phestilla sibogae* from glass and natural surfaces (coralline algae and corals). These initial tests demonstrated that the adhesion capacity after metamorphosis is at least ten-fold greater. We anticipate extending this data set to a publishable form in the next year.

We have recently received coupons prepared under the direction of Dr. J. Montemarano of the Naval Surface Warfare Center in Carderock, MD. These coupons are coated with International Paint Co.'s "Innersleek," the coating which has performed best under test conditions in Pearl Harbor. They will be tested in the very near future. We await new coatings from either ONR, Naval laboratories, or the coatings industry for rapid testing in this excellent instrument.

CONCLUSIONS: An excellent precision flow cell for use in rapid determination of the effectiveness of newly developed and experimental marine coatings has been built and installed at the Kewalo Marine Laboratory. Preliminary testing has proven that it will deliver the desired results. What is necessary at this point is a supply of new coatings, on appropriate coupons, for testing.

SIGNIFICANCE: Newly developed marine coatings, especially those designed to deter firm attachment by fouling organisms – and especially hard fouling organisms such as tube worms and barnacles – can be tested in a matter of 1 – 2 days, instead of the weeks that are required with in-the-sea testing.

PATENT INFORMATION; None. The University of Hawaii is not entitled to patent rights on the precision flow cell.

PUBLICATIONS AND ABSRACTS: None at this early date.

PRESENTATIONS: A summary of the information provided above was presented to the annual ONR "Fouling Release Coatings Program Review," in Baltimore, MD, August 20 – 22, 2001.